2003 THERMAL DEFOLIATION TRIALS

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Abstract

Organic cotton production requires alternatives to harvest aid chemicals for crop termination and fiber quality preservation. In these trials a self-propelled two-row thermal defoliation apparatus was tested in spindle picked and stripper harvested cotton. HVI classing data for thermal, chemical, and untreated control plots were compared. Fiber property data from similar trials in 2002 were presented where data from 2003 trials were not available. Leaf and color grades were improved; thereby increasing fiber value as compared to untreated and chemically defoliated controls. Other fiber properties were not greatly affected. Spinning and yarn properties were mostly unchanged. Rapid desiccation following thermal treatment makes it possible to harvest two days after defoliating. Foreign matter content of seed cotton did not decrease significantly after seven days, indicating completion of plant response. Insect mortality and the possibility of early harvest were additional benefits observed with thermal defoliation.

Introduction

Organic producers are restricted from using standard harvest aid chemicals for desiccation, defoliation and boll opening. Thermal defoliation potentially provides growers an alternative to terminate their crop for better harvest timing, improved fiber quality and greater harvest efficiency. Experiments with thermal defoliation of cotton have been conducted in the past (Funk, 2004). An apparatus designed to transfer heat more quickly compared to earlier devices was tested successfully in 2001 and 2002 (Funk et al., 2004). In 2003 a new two-row thermal defoliator was evaluated in six fields in three states. Fiber and yarn properties are expected to be similar to those from the one-row device tested during 2002.

Materials and Methods

Thermal Treatment Apparatus for 2003

Favorable test results with a one-row treatment device (Funk et al., 2003) led to the design and fabrication of a two row apparatus. Treatment chamber length was increased from 10 to 15 feet. That, and adding a second tunnel, resulted in a three-fold increase in field capacity. Fans powered by a hydraulic motor forced 21,000 cfm of air through a 2.5 M BTU/hr propane burner supplying 380 F air to a plenum lined with one inch nozzles. Hot air from the nozzles passed through the crop canopy. Two-thirds of the heated air was recycled via a suction plenum, improving crop penetration and saving energy. Burner, fans and duct work were suspended beneath a self-propelled high-clearance tractor (PDF 420-G). The tractor's six cylinder 300 in^3 propane fueled engine equipped with hydraulic power for propulsion, steering, air movement and the lift cylinders that added eight additional inches of ground clearance for maneuvering. It also powered a 10 kW generator supplying 220 VAC for a pair of Zimmer™ electric propane vaporizers. An engine governor regulated the throttle setting to maintain 60 hz, as the generator also supplied 110 VAC for data logging and burner safety interlocks. Treatment temperature was controlled by a butterfly valve on the burner fuel supply. The gas valve actuator responded to a digital thermostat connected to 16 thermocouples along the length of both treatment tunnels. The tractor, with defoliation apparatus, was self-loading and self sufficient, an improvement over the first prototype. Two 80 gallon liquid propane tanks onboard carried enough fuel for both burner and engine for a full day of operation (Figure 1).

Field Trials and Demonstrations in the San Joaquin Valley

The primary objective of the field trials at the Shafter Research and Extension Center near Shafter, CA and in a commercial producer's field near Visalia, CA was to compare aphid and silverleaf whitefly (*Aphis gossypii and Bemisia argentifolii*) mortality by thermal defoliation to that achieved by mixtures of chemical defoliants and insecticides. Samples were hand harvested for analysis of stickiness caused by sugary insect excretions.

Field Trials and Demonstrations in New Mexico

The primary objective of the New Mexico field trial was to confirm thermal defoliation and desiccation results at different temperatures and dwell times during a third crop year. Two cultivars, Delta Pine 565 and Acala 1517-99, were randomly assigned to 36 two-row treatment plots, and monitored for leaf loss and leaf browning. Control treatments were two replicate plots of each cultivar receiving chemical treatment, and two each remaining untreated (green). Thermal treatment varied according to a pentagonal response surface experimental design (two replicates per variety at five points, and four replicates at the center) with temperatures ranging from 242 to 289 F, dwell times from 6 to 16 seconds, and fuel consumption from 5 to 13 gallons of propane per acre. Plots were harvested 20 days after treatment (DAT) for analysis of seed cotton, seed, fiber and yarn properties. A separate field was used to compare harvest dates. Three replicates each of four combinations of two harvest dates by two thermal treatment temperatures were picked three and 14 DAT for analysis of seed cotton trash content and fiber quality.

Field Trial and Demonstration on the Texas High Plains

The primary objective of the Lubbock stripper harvested field trial was to ascertain the influence of harvest timing on yields and fiber quality. Thirty-three four-row plots (and guard rows) were planted with a popular stripper harvested cultivar (Paymaster 2260 stacked gene BG/RR) to provide three replicates of each treatment. The four treatments with field cleaning were: harvest three and 20 DAT, 20 days after chemical treatment, and after frost. The seven treatments without field cleaning were the same as with, but added three additional harvest dates seven, nine and 16 days after thermal treatment. One control treatment, a standard tank mix of harvest aid chemicals (1.5 pt/ac Cotton Quick™ and 6 oz/ac Gin Star™) was applied October 21st, the same day as the thermal treatment. The other control, an untreated check, was picked following frost at 42 DAT.

Results and Discussion

Collection and analysis of fiber properties data for the 2003 crop year has not yet been completed. The only numerical results available at this time are trash weights from the ginning of the Lubbock, TX harvest timing trials. Ginning trash weight data only estimates trash content of seed cotton, and has no bearing on fiber properties. For this reason, data from the 2002 crop year is presented. Because the apparatus and treatment parameters used in 2002 were emulated in the construction and testing of the 2003 apparatus, the impact thermal defoliation by either defoliator has on fiber properties is expected to be very similar.

2002 Fiber Properties

Thermal defoliation resulted in more leaves being desiccated compared to standard chemical defoliant treatments. Also, more leaves remained on the plant with thermal defoliation. Consequently, seed cotton in the wagon from thermally defoliated plots had a higher foreign matter (trash) content. However, thermally treated leaves were more dry and crumbly. Seed cotton cleaning equipment removed foreign matter more effectively from thermal treatments than from the control plots. At the gin stand feeder, foreign matter content was not significantly different than the controls. Lint cleaners removed thermal treatment leaf matter more easily as well. In the bale, lint from thermal treatments was cleaner than the lint from the chemically defoliated plots (Table 1).

The higher levels of desiccation and the reduced lint foreign matter content observed with thermal treatment was confirmed at the classing office. Leaf grades were significantly better than the control treatments. And because there were very few green leaves there was less green staining, so color grades were also better. Bale values were higher compared to untreated and chemically defoliated controls (Table 2). There were no significant differences in HVI measures of length, strength and micronaire.

Exposing lint to elevated temperatures (up to 380 F) for brief periods of time (up to 12 seconds) appears to have had no significant impact on most spinning and yarn properties outside of those attributed to the lower trash content of the lint. Unaffected properties (at the 5% level of significance) included: Opening Waste (1.41%), Card Waste (2.15%), Elongation (6.77%), Strength Coefficient of Variation (8.90%) and White Specks per 40 in^2 (1.28). Uster evenness yarn properties that were different were thicks per 1,000 yards and irregularity coefficient of variation (Table 3). Ends down and strength, though not different, are presented (Table 4).

Insect Mortality

The mechanism of thermal defoliation is cooking- leaf proteins are denatured, killing the leaves. Insects on or under the leaves may also be killed (those in the boll are sheltered from brief temperature changes by the thermal inertia of the boll's larger mass). Late season sucking insects that are not killed by the heat would have little food available once desiccation is complete (after 24 hours). Therefore thermal defoliation may be a way of containing stickiness caused by insect secretions should aphid or whitefly populations rise after the bolls open. This potential was demonstrated in 2001 (Table 5) but insect populations were not high enough nor distributed evenly enough to confirm it in 2002.

2003 Field Results

Table 6 presents total lint cleaner waste (lb/bale) for stripper harvested cotton with and without field cleaning after three different defoliation treatments. This can serve as an estimate of the defoliation effectiveness of various treatments. Chemical defoliation reduced the amount of trash material brought to the gin, though this does not necessarily mean the fiber is more valuable (see Table 2). Harvesting plots that were thermally defoliated three days after treatment resulted in approximately 50% more foreign matter in the seed cotton than harvesting them 20 days after treatment. This was possibly due to defoliation occurring in the thermal treatment plots over time. Waiting for a frost (the traditional defoliant) resulted in similar trash levels.

Table 7 presents total lint cleaner waste (lb/bale) for stripper harvested cotton (without field cleaning) on five different dates. There was no statistically significant decrease in lint cleaner waste beyond seven days after treatment. This was possibly due to defoliation occurring mostly in the first week in thermal treatment plots.

Figure 2 illustrates the desiccation achieved by thermal defoliation in Shafter, CA two days after treatment. The two rows in the center of the photo are untreated check rows. This field was treated with an average of 13 gallons of propane per acre. Stickiness results are not yet available.

References

Funk, P.A., C.B. Armijo, D.D. McAlister III, A.D. Brashears, J.S. Bancroft, B.A. Roberts, and B.E. Lewis. 2003. Thermal defoliation. Proc. Beltwide Cotton Conf., Nashville, TN, 6-10 Jan. National Cotton Council, Memphis, TN. pp. 2549-2553.

Funk, P.A. 2004. Thermal Defoliation. Encyclopedia of Agricultural, Food, and Biological Engineering. Marcel Dekker, Inc. New York, NY (in review).

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Table 1. Treatment impact on percent foreign matter at the cotton gin in 2002.

	Percent Foreign Matter		
Treatment	Wagon (Seed Cotton)	Gin Stand Feeder	Bale (Lint Fiber)
Untreated Check	7.7 b	2.8	2.50 a
Chemical Defoliant	7.5 b	2.5	2.51 a
Low Thermal	8.5 ab	2.7	2.47 ab
Medium Thermal	8.8 a	2.5	2.27 b
High Thermal	9.3 a	2.7	2.25 b
OSL	0.0069	NS[a]	0.0202

[a]NS = Not statistically significant at (P > 0.05).

Table 2. Treatment impact on HVI classing office fiber properties that were significantly different for 2002, and on bale value based on classing office grades and loan schedule.

Treatment	*Color Grade (Old Code)*	*Leaf Grade*	*2002 Fiber Value ($/bale)*
Untreated Check	91.5 c	3.83 a	245.88 c
Chemical Defoliant	94.3 b	3.50 ab	251.43 b
Low Thermal	91.5 c	3.25 b	246.50 bc
Medium Thermal	96.0 ab	3.14 b	257.73 a
High Thermal	96.5 a	3.25 b	259.84 a
OSL	<0.0001	0.0042	<.0001

Table 3. Treatment impact on Uster evenness yarn properties for 2002.

Treatment	*NEPS (per 1000 yd)*	*Thicks (per 1000 yd)*	*Thins (per 1000 yd)*	*Irregularity C.V.(%)*
Untreated Check	241	161 a	54.8	15.8 a
Chemical Defoliant	288	146 ab	48.3	15.6 ab
Low Thermal	274	142 abc	51.5	15.7 ab
Medium Thermal	223	130 bc	45.2	15.5 b
High Thermal	237	124 c	45.8	15.5 b
OSL	NS[a]	0.0022	NS[a]	0.0195

[a]NS = Not statistically significant at (P > 0.05).

Table 4. Treatment impact on other spinning and yarn properties

Treatment	Ends Down per M hours	Strength (gram/tex)
Untreated Check	329	11.5
Chemical Defoliant	215	11.6
Low Thermal	174	11.5
Medium Thermal	211	11.5
High Thermal	199	11.6
OSL	NS[a]	NS[a]

[a]NS = Not statistically significant at ($P > 0.05$).

Table 5. Treatment impact on insect mortality for 2001 and 2002 crop years.

	Percent Insect Mortality After Two Weeks	
Crop Year	2001	2002
Untreated Check	8 b	11
Chemical Defoliant	10 b	22
Low Thermal	98 a	-34
Medium Thermal		42
High Thermal	100 a	82
OSL	0.0124	NS[a]

[a]NS = Not statistically significant at ($P > 0.05$).

Table 6. Treatment impact on seed cotton trash content as indicated by lint cleaner waste (pounds per bale) for 2003 field trial in Lubbock, TX.

	Total Lint Cleaner Waste (lb/bale)	
Treatment	With Field Cleaning	Without
Early Thermal (3 DAT)	81.1a	95.8 a
Thermal (20 DAT)	64.4 b	67.9 b
Chemical (20 DAT)	43.2 c	52.6 c
After Frost (42 DAT)	59.4 b	69.6 b
OSL	0.0006	0.0003

Table 7. Harvest date impact on seed cotton trash content as indicated by lint cleaner waste (pounds per bale) for 2003 field trial in Lubbock, TX.

Harvest Date	Days After Treatment	*Lint Cleaner Waste (lb/bale) Without Field Cleaning*
October 24th	3	95.8 a
October 28th	7	76.7 b
October 30th	9	60.9 b
November 6th	16	63.3 b
November 10th	20	67.9 b
OSL		0.0117

Figure 1. Thermal defoliation apparatus used in 2003 (courtesy Gerardo ‘Lalo’ Banuelos)

Figure 2. Thermal defoliation response two days after treatment (courtesy J. Vic Penner).